UPPER EOCENE ORBITOID FORAMINIFERA FROM THE WESTERN SANTA YNEZ RANGE, CALIFORNIA, AND THEIR STRATIGRAPHIC SIGNIFICANCE

BY

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INTRODUCTION

In December, 1929, Dr. W. S. W. Kew and Mr. H. L. Driver invited me to visit with them a locality on the west side of Canada de los Sauces, on the south slope of the western Santa Ynez Range about two miles northwest of Sudden, where they had discovered well-preserved specimens of a small *Discocyclina* in a soft limestone. When we visited this locality we also found almost equally well-preserved specimens of a small stellate "*Discocyclina*". K. E. Lohman and S. W. Lohman, of the California Institute of Technology, accompanied me on a later trip to the same locality in March, 1930, when additional material was collected and the stratigraphic interval between the limestone and the base of the Vaqueros formation was measured.

The limestone is a lens at the base of dark-colored shales and rests disconformably on massive sandstone with an irregular contact (see Pl. 13). At the base of the limestone are pebbles of black chert, presumably derived from Franciscan rocks, and of sandstone, derived from the massive sandstone and its ferruginous concretions on which the limestone rests. The maximum thickness of the lens of limestone is eight feet. The lower one-third to one-half consists of hard limestone made up principally of calcareous algae. The upper part is a soft marly foraminiferal limestone carrying great numbers of orbitoid foraminifera, and also other foraminifera, scattered pieces of calcareous algae, echinoid spines, and a few mollusks. Farther up the slope on the west side of the canyon the limestone thins out and finally near the crest of the ridge is represented only by a limy matrix full of calcareous algae filling holes bored by marine borers that riddle large cobbles and boulders of sandstone derived from the underlying bed. The limestone also lenses out in the opposite direction toward the bottom of the canyon. It reappears in the next little canyon to the west, where it is not more than five feet thick and all of it is hard and more sandy.

C. C. Church called my attention to another locality almost 10 miles southeast of Canada de los Sauces, where he had seen orbitoid-bearing limestone float along Jalama Creek. Kew, Driver, and I traced this float to the outcrop on the steep slope along the south side of Jalama Creek, where the limestone forms prominent white ledges. This limestone also is a lens lying in shales that overlie Upper Cretaceous shales and sandstones. It is very hard, so hard that no specimens can be extracted, but it is full of the same orbitoid foraminifera (see Pl. 17), and also carries other foraminifera, among which a small involute *Operculina* (or *Nummulites*) and a *Gypsina* are the most abundant.

The only locality where stellate orbitoids had been found heretofore in California lies in the San Rafael Mountains 45 miles east of the Jalama Creek locality, where Schenck[1] recorded both a *Discocyclina* and a stellate "*Discocyclina*" from a limestone described by Nelson as the Sierra Blanca limestone[2]. The *Discocyclina* and probably also the stellate species are the same as those found farther west.

The thin sections and photographs were prepared by K. E. Lohman, and the plates were made up and retouched by J. L. Ridgway. I am greatly indebted to Dr. E. Willard Berry, of Ohio State University, for the loan of specimens from Peru for comparison with the California material.

DESCRIPTION OF SPECIES

Discocyclina Gümbel

Gümbel, 1870, Abh. k. bayer. Akad. Wiss., Cl. II, vol. 10, pt. 2 (1868), pp. 687, 690.

Type (by subsequent designation, Galloway, March, 1928, Jour. Pal., vol. 2, No. 1, p. 56).—Orbitoides papyracea Gümbel not Boubée ("*Nummulites papyracea* Boubée")=*Orbitulites Pratti* Michelin, *fide* Schlumberger (Bull. Soc. Géol. France, ser. 4, vol. 3, pp. 274-277, 1903), upper Eocene, southern France.

Discocyclina psila, new species

Plate 14, figs. 2, 4-6; Pl. 15; Pl. 17.

Discocyclina sp. indet., Schenck, 1929, Trans. San Diego Soc. Nat. Hist., vol. 5, No. 14, pp. 227-228, pl. 30, fig. 1.

A small, very thin, flat or slightly warped *Discocyclina* bearing

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1 Schenck, H. G., Trans. San Diego Soc. Nat. Hist., vol. 5, No. 14, pp. 221, 227-228, 1929.

2 Nelson, R. N., Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 15, No. 10, pp. 352-354, 1925.

minute granules over the entire surface. The central part is not inflated, the surface of the test rising as a very low broad dome, the outline of which forms a smooth curve from edge to edge.

The diameter of 69 specimens, representing the most perfect tests that were freed from the matrix, ranges from 1.2 mm. to 4.7 mm., the average being 2.8 mm. Two maxima are represented in these measurements, one at 2.6 mm. and the other at 3.0 mm. It was suspected that they represented megalospheric and microspheric forms, respectively, but the specimens that were ground down were found to be megalospheric regardless of size. The average thickness of 25 specimens is 0.5 mm., the range being 0.5 to 0.7 mm. The surface is minutely granular in a diffused irregular fashion, but not papillate.

The median chambers are short rectangles. According to measurements on 7 thin sections they have a radial length of 30 μ near the center and as much as 70 μ or 80 μ toward the edge, and a width of 30 μ to 40 μ. The length is quite irregular in different annuli. Chambers in the same annulus communicate by passages at the outer edge that have a width of about 2 μ to 8 μ (see Pl. 15, fig. 4). These passages can not be seen on all sections nor on all parts of the same section. The thickness of the wall between successive annuli is 8 μ to 10 μ, whereas the wall between chambers of the same annulus has a thickness of 6 μ to 8 μ.

Near the center of the test the lateral chambers consist of 6 or 7 tiers, which are not arranged in definite vertical rows, but more or less overlap in successive tiers. According to measurements on two thin sections, the laterals have a height of only 8 μ, whereas the roof between them has a thickness of 11 μ to 19 μ. The height of the median chambers increases from 11 μ near the center to 23 μ near the edge. Minute pillars spring from the roof of the median chambers, but they fail to extend beyond the first tier of laterals.

The megalospheric nucleoconch consists of an initial spherical chamber, having a diameter in two sections of 80 μ and 95 μ, respectively, partly embraced by a larger second chamber. In the same two sections the entire nucleoconch has a diameter of 160 μ and 170 μ, respectively.

Type material.—5 cotypes (Calif. Inst. Tech. No. 1148) and 6 paratypes (Calif. Inst. Tech. Nos. 1147, 1150-1153, 1156), all figured. Paratypes (San Diego Soc. Nat. Hist. No. 332), figured; (also Nos. 336, 337). Paratypes have also been deposited at the U. S. National Museum, California Academy of Sciences, Scripps Institution of Oceanography, Stanford University, and the University of California.

Type locality.—South slope of western Santa Ynez Range, Santa Barbara County, California, west side of Canada de los Sauces 1.2 miles above coast (in center of first "O" in "Concepcion" on Guadalupe sheet), upper part of limestone reef; W. S. W. Kew, H. L. Driver, and W. P. Woodring, collectors; Calif. Inst. Tech. Loc. No. 595.

Other localities.—North slope of western Santa Ynez Range, Santa Barbara County, California, spur overlooking Jalama Creek, 0.5 mile N. 28° E. from 1402-Hill, lens of hard limestone; W. S. W. Kew, H. L. Driver, and W. P. Woodring, collectors; Calif. Inst. Tech. Loc. No. 596; sections only. South slope of San Rafael Mountains, Santa Barbara County, California, upper Mono Creek, Sierra Blanca limestone (Schenck).

This is a very small and thin species. Sections ground from specimens from the type locality that are readily extracted from the matrix agree closely with sections in the hard limestone on Jalama Creek and the section from the Sierra Blanca limestone described and figured by Schenck.

D. psila is similar to only a few of the 26 named American species of *Discocyclina,* most of which are far thicker and many of which have a distinct central boss. The following three species have already been recorded from California and Lower California. *D. clarki* Cushman,[3] originally described from beds north of Coalinga referred by B. L. Clark to the Meganos formation and recorded by Schenck from beds bordering the Simi Valley referred to the Domengine formation by B. L. Clark, is larger and has a slightly inflated central boss and strong papillae. *D. californica* Schenck[4], a species of doubtful Tejon age from Santa Clara County, has a very thick central part and a thin peripheral flange. *D. cloptoni* Vaughan[5], a "middle or upper Eocene" species from Lower California, is fully twice as large and its megalospheric nucleoconch has two, four, six, or eight chambers. *D. psila* is not closely allied to any of these, but is similar to the following small very thin American species. *D. perkinsi* Vaughan[6] (upper Eocene, Jamaica) is considerably larger (diameter 6.5 mm. to 7.0 mm.) and has smaller median and lateral chambers. *D. citrensis* Vaughan[7] (upper Eocene, Florida) has a broad

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3 CUSHMAN, J. A., U. S. Geol. Surv. Prof. Paper 125, pp. 41-42, pl. 7, figs. 4-5, 1920. Schenck, H. G., Trans. San Diego Soc. Nat. Hist., vol. 5, No. 14, pp. 221-224, pl. 27, figs. 1, 2, 5, text fig. 7, 1929.

4 SCHENCK, H. G., Trans. San Diego Soc. Nat. Hist., vol. 5, No. 14, pp. 224-227, pl. 27, figs. 3, 4, 6; pl. 28, figs. 2-6; pl. 29; pl. 30, figs. 2-3, text figs. 8-10, 1929.

5 VAUGHAN, T. W., Proc. U. S. Nat. Mus., vol. 76, art. 3, pp. 14-15, pl. 5, figs. 1-6, 1929.

6 VAUGHAN, T. W., Jour. Pal., vol. 1, No. 4, p. 285, pl. 46, figs. 4-5, 1928.

7 VAUGHAN, T. W., Florida Geol. Survey Nineteenth Ann. Rpt., pp. 159-160, pl. 2, figs. 1-5, 1928.

low central boss and is densely papillate. *D. salensis* (W. Berry[8]) (upper Eocene, Peru) is about twice as large, and also has a broad low central boss and coarse papillae. *D. psila* is most closely allied to *D. perpusilla* Vaughan[9], found in the Guayabal formation (upper middle Eocene, according to Vaughan) at several localities in the State of Vera Cruz, Mexico. Both species have many essential features in common, the most striking of which are the presence of minute pillars adjoining the equatorial chambers, but not extending between the lateral chambers, which overlap in successive tiers, and the location of passages between median chambers of the same annulus at the outer edge of the annulus. *D. perpusilla,* however, is even smaller (diameter 0.6 mm. to 2.3 mm.) and thinner. Inasmuch as it is thinner it has fewer tiers of lateral chambers. Though these differences are not very great, they seem to justify a new name in view of the difference in geographic range and the apparent difference in age. If the Guayabal formation were upper Eocene, *psila* would be regarded as a California race of *perpusilla.* It is now regarded as a later mutation.

Actinocyclina Gümbel

Gümbel, 1870, Abh. k. bayer. Akad. Wiss., Cl. II, vol. 10, pt. 2 (1868), pp. 688 (*Aktinocyclina*), 707 (*Actinocyclina*).

Type (by subsequent designation, Galloway, March, 1928, Jour. Pal., vol. 2, No. 1, p. 57).—Orbitolites radians d'Archiac, upper Eocene, southern France.

Whether *Actinocyclina* is regarded as a separate genus or as a subgenus of *Discocyclina* is a matter of preference. It has the same essential structure as *Discocyclina,* but in view of the large number of species of orbitoids characterized by rectangular median chambers and in view of the striking difference afforded by the presence or absence of stellate rays, it might as well be given generic rank. It is here used as a genus to embrace all species bearing stellate rays. *Asterocyclina* Gümbel[10], characterized by a small number of rays that greatly modify the outline of the test, is regarded as a synonym of *Actinocyclina,* or as a minor subdivision. Any

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[8] BERRY, WILLARD, Jour. Washington Acad. Sci., vol. 19, No. 7, p. 143, figs. 1-2, 1929.

[9] VAUGHAN, T. W., Proc. U. S. Nat. Mus., vol. 76, art. 3, pp. 9-11, pl. 2, figs. 3-5, 1929.

[10] GÜMBEL, C. W., Abh. k. bayer. Akad. Wiss., Cl. II, vol. 10, pt. 2 (1868), pp. 689, 713, 1870. Type (by subsequent designation, Galloway, March, 1928, Jour. Pal., vol. 2, No. 1, p. 58), *Orbitoides stellata* Gümbel not d'Archiac ("*Calcarina? stellata* d'Archiac") = *Asterodiscus pentagonalis* Schafhäutl, *fide* Galloway. Galloway's genotype citation is hardly in proper form.

lot of stellate orbitoids generally consists mostly or wholly of broken specimens and the outline of the test can not very well be judged from such material. The rays are more durable than the thin web between them and broken specimens generally have a misleading stellate outline. At all events even if *Asterocyclina* is recognized, the large number of rays and the slight notching of the edge of the test place the following species in *Actinocyclina.*

The taxonymy and nomenclature of *Discocyclina* and its allies are considerably complicated by the recent description by W. Berry[11] of a very remarkable upper Eocene species from Peru that has five-rayed median chambers and no indication of exterior rays, for which the name *Asterodiscocyclina* was proposed as a subgenus of *"Orthophragmina"*.

Actinocyclina aster, new species

Plate 14, figs. 3-6; Pl. 16; Pl. 17.

A thin *Actinocyclina* of medium size bearing a relatively broad moderately inflated central boss and 5 to 13 rays. On well-preserved specimens the rays barely modify the outline of the edge of the test, shallow notches lying in the interradial areas. The central boss and rays bear moderately small papillae, which are smaller toward the ends of the rays. The interradial areas bear very minute papillae or none at all, except near the boss, where they are of about the same size of those on boss and rays.

The diameter of 17 of the most perfect specimens ranges from 5.6 mm. to 10.2 mm., but all except two, which have diameters of 10 mm. and 10.2 mm., respectively, are badly broken around the edge. A lot of 38 broken specimens shows a thickness range of 0.7 mm. to 1.3 mm., the average being 1.0 mm. In 2 specimens of varying size the diameter of the central boss is 0.9 mm. to 1.8 mm. The average is 1.2 mm.

Twenty-three specimens that are not broken too far back to reveal the full number of rays have 5 to 13 rays, the average of which is between 8 and 9. On the only specimens that have the edge of the test almost unbroken (none is entirely perfect) the rays flatten out within about 1 mm. of the edge. The arrangement of rays is almost as variable as the number. Some specimens have relatively broad low rays that may bifurcate. Others have narrow high rays that generally are undivided. Both forms are shown on Plate 14. On most specimens all the rays spring from the central boss,

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11 Berry, E. Willard, Eclogae Geol. Helvetiae, vol. 21, No. 2, pp. 405-407, pl. 33, 1928

but a few have primary rays (for example, 6 or 8) and secondary rays in some of the interspaces that fail to reach the boss.

According to a few measurements, the papillae on the central boss have a diameter of 65 μ to 125 μ. Out on the rays the diameter decreases to 30 μ or even less. Narrow rays may have a single row of closely spaced papillae. Horizontal sections of such specimens may show a solid ray (Pl. 16, fig. 1), which apparently is to be attributed to the deposition of calcite between the closely spaced papillae during the process of fossilization, thus forming a solid calcite structure.

The median chambers are elongate rectangles. According to random measurements or seven thin sections, they have a radial length of 50 μ to 80 μ and a width of 25 μ to 40 μ. Chambers in the same annulus communicate by passages along the inner edge that have a diameter of about 2 μ to 4 μ. The wall separating successive annuli is slightly thicker than the wall between chambers of the same annulus (8 μ to 12 μ as compared with 4 μ to 6 μ). Near the plane of the median chambers the rays have a width of 30 μ to 65 μ.

The lateral chambers are piled up in vertical columns consisting of 16 or 17 tiers near the center of the test and of 5 or 6 out near the edge. These chambers have a height of 19 μ to 27 μ and the roof has a thickness of 6 μ to 8 μ. Both sets of measurements were made on three sections. The height of the median chambers increases from 23 μ near the center to 68 μ near the edge. As seen in vertical section the walls between them are strongly convex outward. The perforations could not be distinguished.

All specimens that were ground down show a megalospheric nucleoconch consisting of a small initial chamber partly embraced by a larger second chamber. In four specimens the initial chamber has a diameter of 80 μ to 160 μ, and the maximum diameter of the entire nucleoconch is 175 μ to 225 μ.

Type material.—Holotype (Calif. Inst. Tech. No. 1146) and 3 paratypes (Calif. Inst. Tech. Nos. 1147, 1154, 1155), all figured. Paratypes (San Diego Soc. Nat. Hist. Nos. 332-334), figured. Paratypes have also been deposited at the U. S. National Museum, California Academy of Sciences, Scripps Institution of Oceanography, Stanford University, and the University of California.

Type locality.—South slope of western Santa Ynez Range, Santa Barbara County, California, west side of Canada de los Sauces 1.2 miles above coast (in center of first "O" in "Concepcion" on Guadalupe sheet), upper part of limestone reef; W. S. W. Kew, H. L. Driver, and W. P. Woodring, collectors; Calif. Inst. Tech. Loc. No. 595.

Other localities.—North slope of western Santa Ynez Range, Santa Barbara County, California, spur overlooking Jalama Creek, 0.5 mile N. 28° E. from 1402-Hill, lens of hard limestone; W. S. W. Kew, H. L. Driver, and W. P. Woodring, collectors; Calif. Inst. Tech. Loc. No. 596; sections only.

The broad-rayed and narrow-rayed forms are quite different, but in view of the intergrading and integrating characters it seems unreasonable that more than one species is represented. Both forms have the same kind of boss and papillae and, in so far as the evidence furnished by a few sections goes, the same kind of internal features, excepting the solid subsurface rays of some of the narrow-rayed specimens, which is regarded as due to changes during fossilization. Both broad rays and narrow rays are simple or bifurcate, though bifurcation is rare in narrow rays. Yet the differences separating these two forms are almost as great as those separating *Actinocyclina mariannensis* (Cushman)[12] and *A. americana* (Cushman)[12], which are found together in the upper Eocene Ocala limestone of Florida. *A. mariannensis* has a maximum recorded diameter of 18 mm. and bears 8 to 11 undivided rays, all of which generally spring from the small mammillary boss. *A. americana* has a maximum recorded diameter of 25 mm., but two magnificent specimens recently collected by W. P. Popenoe in the quarry of the Florida Basic Rock Co., 10 miles northwest of Marianna, Florida, and now in the collections of the California Institute of Technology, have a diameter of 35 mm. and 42.5 mm., respectively, and the edge of the test is broken on both. The rays of *americana* are irregularly arranged, due to the intercalation of secondary rays that fail to reach the boss. Those that spring from the boss may be undivided or may bifurcate. The total number of rays is as high as 22, but the number that spring from the boss is about the same as in *mariannensis*. Both forms have the same characteristic small mammillary boss and in both the papillae vary in size and prominence.

Twenty-three species and varieties of American stellate "Discocyclinas" have been named, but a number of them are synonyms. The California species needs comparison with only a few. As already indicated, it is much like *A. mariannensis* and *A. americana* aside from the great difference in the size of the test and in the relative size of the central boss. *A. subtaramellei* (Cushman)[13], an upper Eocene species from Cuba, still

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12 CUSHMAN, J. A., U. S. Geol. Survey Prof. Paper 125, pp. 46-47, pl. 11, 1920. *"Orthophragmina" mariannensis* var. *papillata*, found with *mariannensis* s. s. and *americana*, is hardly worth distinguishing under a separate name.

13 CUSHMAN, J. A., Carnegie Inst. Washington Pub. 291, pp. 53-54, pl. 10, fig. 2; pl. 15, figs. 1-3, 1919. U. S. Geol. Survey Prof. Paper 125, pp. 45-46, pl. 10, figs. 2-3, 1920.

is imperfectly known, for the material on which it was based clearly is badly broken. *A. aster* is closely allied to *A. calita* (W. Berry)[14], described from beds near Calita Sal in Peru correlated with the upper Eocene Saman conglomerate. The Peruvian material also is badly broken. So far as it goes it closely resembles narrow-rayed specimens from California, but pillars and papillae are entirely absent. The surface of *A. calita* bears a reticulate network, due to the emergence of the columns of lateral chambers, which are protuberences or pits depending on the preservation.

STRATIGRAPHIC SIGNIFICANCE

In America *Discocyclina* is found in deposits of lower, middle, and upper Eocene age, whereas *Actinocyclina* has so far been recorded only from upper Eocene beds, though in Europe it also is found in middle Eocene deposits. In eastern United States *Actinocyclina* is recorded only from the Ocala limestone of Florida, Georgia, and Alabama. It is wide-spread in the West Indies, Central America, and northern South America. Independent evidence points to an upper Eocene age for these *Actinocyclina*-bearing beds at so many places that its presence has come to be considered sufficient evidence in itself for establishing the age. It can be claimed that the *Actinocyclina*-bearing beds of the Santa Ynez Range afford the most precise datum plane for establishing correlations between the Eocene sections of the Pacific and Gulf coasts that has so far been discovered. I know of no other genus found in both regions that has such a limited stratigraphic range. This statement is made with full realization of the ecologic requirements of *Actinocyclina,* which is found only in limestone or marl, or rarely in calcareous sandstone, and therefore tolerated only clear water. This facies control is clearly shown in Georgia, where *Actinocyclina* is found in the Ocala limestone and in the Tivola tongue of the Ocala as far north as the central part of the state, but not in the terrigenous sediments of the Barnwell formation of Jackson age, with which the Ocala limestone interfingers.[15] The same relations are shown in Alabama.[16] The absence of *Actinocyclina* in older Eocene deposits on the Gulf coast might be attributed to the absence in that part of the section of pure limestones like the Ocala limestone. Clear warm water is indi-

14 BERRY, W., Jour. Washington Acad. Sci., vol. 19, No. 7, pp. 143, 145, figs. 3-4, 1929.

15 COOKE, C. W., and SHEARER, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120, pp. 41-81, 1918.

16 COOKE, W., in ADAMS, G. I. and others, Geology of Alabama: Alabama Geol. Survey Special Rpt. No. 14, pp. 274-279, 1926.

cated, however, by the Yellow Limestone of Jamaica and by the Plaisance limestone of Haiti, both of which are of middle Eocene age (about Lutetian), yet *Actinocyclina* is not found in them. The absence of any orbitoids in the Plaisance limestone probably is due to insufficient collecting, for *Discocyclina* is represented in the Yellow Limestone.[17] The limestones and marls of the Vicksburg group of the eastern Gulf states and similar deposits of the same age in the West Indies offer a suitable facies in beds of Oligocene age, but "*Lepidocyclina*" is the only orbitoid found in them.

According to the preceding discussion the narrowly limited stratigraphic range of *Actinocyclina* can hardly be attributed to facies control. Therefore, it is concluded that the *Actinocyclina*-bearing beds of the Santa Ynez Range are of upper Eocene age, as Schenck suggested for the Sierra Blanca limestone, for there is no reason to believe that this genus lived earlier or later in California than elsewhere in America. Not only are the species of *Discocyclina* and *Actinocyclina* of the Santa Ynez Range similar to those in the Ocala limestone, but a large flat *Operculina,* represented by a few imperfect specimens collected at the locality on Canada de los Sauces (see Pl. 14, fig. 1), is very similar to *O. ocalana* Cushman.[18] This species or a closely allied one also is recorded from Panama and Ecuador.[19] So far as orbitoid and nummulitoid foraminifera are concerned the only striking difference between the California deposits and the Ocala limestone is the absence of "*Lepidocyclina*" in California. Though this genus has an extensive world-wide distribution in tropical and subtropical regions it has not yet been recorded on the Pacific coast of America north of Nicaragua.

If these deposits in the Santa Ynez Range are of upper Eocene age, the question arises as to what part of the Eocene section of the Pacific Coast is represented by them. Unfortunately not enough detailed mapping and precise zonal stratigraphy has been carried out in this region, at least not for publication, but the following preliminary considerations are offered.

The section on Canada de los Sauces is as follows:

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17 VAUGHAN, T. W., Bull. Geol. Soc. Am., vol. 35, No. 4, p. 791, 1924. Jour. Pal., vol. 1, No. 4, p. 279, 1928 (quotation from Matley). Jour. Pal., vol. 2, No. 1, p. 11, 1928.

18 CUSHMAN, J. A., U. S. Geol. Prof. Paper 128, p. 129, pl. 19, figs. 4-5, 1921.

19 VAUGHAN, T. W., Proc. Nat. Acad. Sci., vol. 12, No. 8, pp. 519, 533, 1926.

SECTION ON CANADA DE LOS SAUCES ABOUT TWO MILES NORTHWEST OF SUDDEN

	Thickness in Feet
4. Vaqueros conglomerate and sandstone carrying *"Pecten" magnolia* and *Turritella inezana*. Disconformity	
3. Dark-colored shale carrying at base a lens (maximum thickness 8 feet) of yellowish gray limestone, at the base of which are pebbles of chert and sandstone, and boulders of sandstone. The limestone carries calcareous algae, foraminifera, echinoid spines, and a few mollusks. A few feet of thin-bedded sandstone alternating with shale lies 78 feet above base. Uppermost beds consist of sandstone. Shale exposed only at rare intervals. (Thickness measured.) Disconformity	183
2. Massive sandstone carrying ferruginous sandstone concretions. Nature of contact with No. 1 not known. (Thickness estimated.)	135
1. Dark gray shale.	

The gray shale at the base of the section probably is of Upper Cretaceous age, for H. L. Driver reports that in a branch of this canyon farther up the slope of the range he collected from it a shell fragment consisting of fine fibers that suggest *Inoceramus*. The overlying massive sandstone apparently is of Eocene age, as it resembles massive Eocene sandstone farther east. No. 3 of the section, at the base of which the *Actinocyclina*-bearing limestone lies, may embrace more than one stratigraphic unit, but no evidence could be found to subdivide it on the basis of the meager exposures. The interval to the base of the Vaqueros conglomerate was measured in the next little canyon west of Canada de los Sauces, where the attitude of the beds could be more accurately determined. It is apparent that this abbreviated and condensed section does not help very much in determining the age relations of the *Actinocyclina*-bearing limestone. Nor do the other fossils. The only mollusks are fragments of a large oyster, apparently *Ostrea tayloriana* Gabb, and imperfect specimens probably representing *Globularia* and *"Arca"*. The significance of the remaining fossils—calcareous algae, other foraminifera, and echinoid spines—is still unknown.

So far as now known the closest area where a considerable thickness of fossiliferous Eocene deposits crops out lies in the vicinity of Gaviota Pass. The following preliminary summary of the Eocene stratigraphy of this region is based on the work of A. Clark and L. C. Hookway, both formerly of the California Institute of Technology, who carried on field work there during the summer of 1929. On the north slope of the range, north of Gaviota Pass, the oldest fossiliferous Eocene rocks (Loc. 403) carry a form of *Globularia hannibali* (Dickerson) like that found in Simi Valley and at other localities referred to the Domengine "horizon".[20] These beds are tentatively considered of Domengine age. In the next higher fossiliferous beds (Loc. 401) are found *Nerita triangulata* Gabb, a large form of *"Euspirocrommium" clarki* (Stewart), *Corbis,* and *"Macrocallista" conradiana* (Gabb)?. Though *Nerita triangulata* has been regarded as a Domengine species, these beds probably are younger than Domengine. The following fossils have been recognizd in still higher beds in the same section (Loc. 389) : a very large form of *"Euspirocrommium" clarki* (Stewart), like the one found at Tejon, *Loxotrema turritum* Gabb?, a *Turritella* intermediate between *T. uvasana* Conrad and *T. variata* Conrad (*"lompocensis* Arnold"), *Ficopsis hornii* Gabb, a gastropod allied to *"Siphonalia" tularensis* Anderson and Hanna (Pl. 11, fig. 7)[21], another allied to *"Siphonalia" merriami* Wagner and Schilling, *"Phos" blakianus* Anderson and Hanna? (Pl. 8, fig. 16)[21], *Strepsidura ficus* (Gabb), a form of *Venericardia hornii* Gabb, and *"Macrocallista" conradiana* (Gabb). This is a strange fauna combining a number of distinctive Tejon species with others that indicate a later age. The *Loxotrema,* which generally is considered a Domengine species, probably means nothing more than a brackish-water element, which is also attested to by a *Potamides.* These beds are regarded as a little younger than Tejon. They constitute a well-defined horizon that has been recognized as far west as Jalama Ranch, where they were found by J. R. Dorrance.

Lying higher in the section, but separated from the deposits just described by a fault, are beds characterized at many places by the abundance of "*Crassatellites*". On Nojoqui Creek east of the highway (Loc. 380) they carry *Turritella "lompocensis* Arnold" (a synonym of *T. variata* Conrad), *"Pecten" yneziana* Arnold, which is almost indistinguishable from *"Pecten" perrini* Arnold of Vaqueros and Temblor age, *"Crassatellites" collina* (Conrad), and a form of *Venericardia hornii* Gabb. This fauna is widespread in this region and has been recorded at

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20 Clark, B. L., The Domengine horizon, middle Eocene of California: Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 16, No. 5, pp. 99-118, 1926.

21 These citations refer to illustrations in F. M. Anderson and G. D. Hanna, Occ. Papers Calif. Acad. Sci., No. 11, 1925.

several localities by Arnold and Anderson[22], who considered it of Tejon age. The abundant species vary from place to place, but it is not known whether this difference in distribution has any zonal significance. At some localities a giant *"Cardium,"* erroneously identified as *Cardium brewerii* Gabb by Arnold, and a large *Glycymeris,* listed as *Glycymeris* cf. *veatchii* Gabb var. *major* Stanton by Arnold, are abundant. At many other places *"Crassatellites" collina* is the prevailing species. At still others the only fossils are numerous specimens of *Ostrea tayloriana* Gabb, which was called *Ostrea idriaensis* Gabb by Arnold.[23] Despite the difference in distribution of some of the species, several, particularly *Turritella variata, "Pecten" yneziana,* and *"Crassatellites" collina,* are widely distributed and show that the same series of beds is represented. These deposits are found on the south slope of the range along the highway on Gaviota Creek. Here the highest horizon that has yielded abundant fossils (Loc. 386) is characterized by the following: *Turritella variata* Conrad, *Ficus gesteri* Wagner and Schilling (*Ficus mamillatus* Gabb of Arnold[24]), *"Siphonalia" merriami* Wagner and Schilling (probably *Fusus occidentalis* Gabb of Arnold[24], U. S. Geol. Survey Bull. 321, pl. 10, fig. 2, 1907), and *"Strepsidura" lorenzana* Wagner and Schilling. Thomas Antisell, who accompanied one of the parties of engineers sent out by the War Department in 1853 to explore routes for a transcontinental railroad, was the first one to collect from these beds and also from the Vaqueros formation of this region. He may not have been much of a geologist, but his lists[25] bear witness to the care that he took to do what many modern geologists fail to do; that is, to collect fossils bed by bed and to keep the collections separate. Modern writers who attempt to hang the name *Pachydesma inezana* Conrad on a Vaqueros *Tivela* are simply ignoring the record. I do not know whether the type of this species is extant, but I am willing to place enough confidence in Antisell to predict that it is an Eocene mactroid or a young *"Crassatellites"*, even though Conrad described the hinge. If Antisell's lists had not been ignored or had been taken more

22 ARNOLD, RALPH, and ANDERSON, ROBERT, U. S. Geol. Survey Bull. 322, p. 32, 1907.

23 If these names are synonyms *tayloriana* has precedence. It would be very remarkable to find *O. tayloriana* in the Pliocene deposits of Cedros Island (see Jordan and Hertlein, Proc. Calif. Acad. Sci., 4th ser., vol. 15, No. 14, p. 428, 1926). After this was written I discovered that Hertlein had renamed the Cedros Island species *O. erici* (Jour. Pal. vol. 3, No. 3, p. 295, 1929).

24 Perhaps the names that Arnold used are the proper ones for these species, which have not yet been adequately studied.

25 ANTISELL, THOMAS, U. S. Pacific R. R. Rpts., vol. 7, pt. 2, p. 73, 1856.

seriously, the error of "painstakingly determining" that the name *Turritella variata* Conrad should be attached to a form of *Turritella inezana* might have been avoided.[26]

These beds that carry *Turritella variata* have been called Oligocene,[27] but they clearly are Eocene, for there is no more reason to believe that the giant Venericards survived until Oligocene time in California than to believe, as was once claimed, that ammonites became extinct at the close of Cretaceous time everywhere in the world except in California. That they are younger than the Tejon formation is beyond dispute. They, therefore, represent a group of Eocene deposits lying above the Tejon and according to available evidence are of upper Eocene age. They should have a name, but it seems inadvisable to propose a name before a great deal of detailed work has been done in this region. For the present they will be referrd to as the *Turritella variata* zone. At least part of the deposits at the south end of the San Joaquin Valley described by Wagner and Schilling[28] as the San Emigdio and Pleito formations fall in the *Turritella variata* zone, but more study is required to determine whether the San Lorenzo formation and the Lincoln "horizon" of Washington, with which these deposits have been correlated, also embrace beds of upper Eocene age.

The fauna of the *Turritella variata* zone is a strange one to be of Eocene age and it is not surprising that it has been called Oligocene. From what region did the strange species come that are utterly different from those of the preceding Eocene of California? They certainly did not come from the Gulf Coast, where Pacific Coast paleontologists are accustomed to look for Pacific cryptogenetic stocks, more as a matter of tradition and respect. The youngest Eocene beds there (Jackson formation) carry a fauna that is very much like that of the preceding Claiborne group, with which the Tejon fauna is traditionally compared. Apparently these stocks are indigenous to the Pacific and it is necessary to look farther afield around the borders of the Pacific. According to Olsson,[29] the Saman conglomerate of Peru, which lies at the top of the Eocene, has a fauna consisting of a few persistent Eocene stocks combined with others that elsewhere

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26 WIEDEY, L. W., Trans. San Diego Soc. Nat. Hist., vol. 5, No. 10, pp. 120-121, 1928.

27 CLARK, B. L., Stratigraphy and faunal horizons of the Coast Ranges of California, p. 18 [Berkeley, 1929]. Unfortunately this pamphlet was issued without any indication of place or date of publication.

28 WAGNER, C. M., and SCHILLING, K. H., Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 14, No. 6, pp. 235-276, pls. 43-50, 1923.

29 OLSSON, A. A., Bull. Am. Pal., vol. 14, No. 52, pp. 58-61, (12-15), 1928.

are characteristic of Oligocene and Miocene deposits. This description fits the fauna of the *Turritella variata* zone admirably, but aside from the presence of giant Venericards in both and the remote similarity of *Turritella samanensis* Olsson to *T. variata* the described Saman mollusks are not much like those of the *variata* zone. Closer affinities involving some of the most striking species of the *variata* zone are apparent in the early Tertiary faunas of Japan. Nagao's[30] recent interesting account reveals the following:

SIMILAR FOSSILS FROM JAPAN AND FROM TURRITELLA VARIATA ZONE OF CALIFORNIA

Japanese species	*Species from Turritella variata zone*
Turritella karatsuensis Nagao	Turritella variata Conrad
"Chrysodomus" asakuraensis Nagao	"Siphonalia" merriami Wagner and Schilling
Glycymeris cisshuensis Makiyama	Glycymeris sp. (Glycymeris cf. veatchii Gabb var. major Stanton of Arnold)
"Pecten" ashiyaensis Nagao	"Pecten" yneziana Arnold
"Crassatellites" yabei Nagao	"Crassatellites" collina (Conrad)
"Cardium" hizenense Nagao	"Cardium" sp. (Cardium brewerii Gabb of Arnold)

The roots of several of the most characteristic California species seem to extend across the Pacific to Japan or to some still unknown region that sent migrants to both Japan and California. The Japanese species recorded above, except *"Chrysodomus" asakuraensis* and *"Cardium" hizenense*, both of which are referred to the upper Eocene, are recorded from beds that are considered of lower Oligocene age, but perhaps these age assignments have been influenced by the inclusion of far too much in the California Oligocene.

It is apparent that in the western Santa Ynez Range is a series of beds that on the basis of the fossil mollusks is of upper Eocene age and that they carry a strange Pacific fauna. They can without much hesitation be correlated with the Ashiya group of Japan. The *Actinocyclina*-bearing limestones also are upper Eocene and are to be correlated with the Saman conglomerate of Peru and with the Ocala limestone of Florida. The inference naturally follows that both sets of beds are synchronous, but however reasonable it is it still is a matter of inference, for the two sets of fossils have not yet been found together. Beds carrying the *Turritella*

30 NAGAO, T., Palaeogene fossils of the island of Kyûshû, Japan, Pt. 2: Sci. Rpts. Tôhoku Imp. Univ., ser. 2, vol. 12, No. 1, pp. 11-140, pls. 1-17, 1928.

variata fauna crop out within two miles (Arnold and Anderson's locality 4518 and vicinity) of the *Actinocyclina* locality in Canada de los Sauces and perhaps detailed work will more clearly show the stratigraphic relations. The orbitoid foraminifera and the large *Operculina* are migrants from the American tropics. They show in the clearest manner that during the latter part of Eocene time marine animals could freely migrate between the Caribbean Sea and the Pacific, though convincing evidence on this point was already available. Why many of the Jackson mollusks failed to migrate with the foraminifera and why the peculiar mollusks of the *Turritella variata* zone failed to gain a foothold in Atlantic waters are matters of speculation. At first glance it may seem strange to claim that tropical migrants lived along the California coast at the same time and in the same region with north Asiatic migrants. They represent, however, wholly different ecologic facies. The orbitoids lived only in places where virtually no terrigenous material was being deposited, whereas the mollusks of trans-Pacific affinities lived where sand and mud were accumulating.

A great deal still remains to be learned about the Eocene deposits of the Santa Ynez and San Rafael ranges. It would be interesting to know whether the Eocene beds that, according to Nelson's mapping, overlie the Sierra Blanca limestone carry any fossils. Nelson[31] also records an Eocene limestone in the western San Rafael range that carries "*Orthophragmina*", giant Cerithia, and echinoids of the genera *Linthia* and *Amblypygus,* the latter described by Israelsky.[32] Beds, possibly of the same age, carrying giant Cerithia, as well as *Velates,* a form of *Globularia hannibali* (Dickerson), a *Turritella* allied to *T. lawsoni* Dickerson, *Pseudomiltha,* and *Pholadomya,* are found far to the east in the San Rafael Range near the eastern border of the Mt. Pinos quadrangle, where they were discovered by J. R. Dorrance. They fall somewhere in the middle Eocene, near the Domengine, but the fauna is unlike any other Domengine fauna. On the whole this region is the most fascinating one in California to anyone interested in Eocene stratigraphy and paleontology. The relations of the upper Eocene beds of the western Santa Ynez Range to the marine deposits into which the Sespe formation is described as grading in this region[33] also offers an interesting field for investigation.

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31 Nelson, R. N., Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 15, No. 10, p. 348, 1925.

32 Israelsky, M. C., Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 14, No. 11, pp. 377-396, 1923.

33 Reed, R. D., Sespe formation, California: Bull. Am. Assoc. Petroleum Geologists, vol. 13, No. 5, pp. 489-507, 1 fig., 1929.